VOLUME I

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TITLE

QUALIFICATION TEST REPORT FOR 450 GALLON CRASHWORTHY FUEL TANK FOR U.S. AIR FORCE H-53 HELICOPTER

TEST PERFORMED BY

FIBER SCIENCE DIVISION

CONTRACT NUMBER

F09603-79-C-1642-P20002

PREPARED BY

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APRIL 2, 1982

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ROBINS AIR FORCE BASE, GEORGIA 31098

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EXTERNAL FUEL TANK
FILAMENT WOUND
QUALIFICATION TEST REPORT

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

THE FILAMENT WOUND, CRASHWORTHY 450 GALLON H-53 EXTERNAL FUEL TANK WAS SUBJECTED TO A SERIES OF QUALIFICATION TESTS TO VERIFY THE DESIGN. THE TESTS DESCRIBED WITHIN THE REPORT INCLUDE PHYSICAL MEASUREMENTS, PRESSURE, SLOSH & VIBRATION, STATIC LOAD, VAPOR IGNITION, BALLISTIC, FUEL FIRE & CRASH IMPACT.

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CERTIFICATION

Fiber Science Division, 506 North Billy Mitchell Road, Salt Lake City, Utah, hereby certifies that six (6) 450 gallon pre-production filament wound composite crashworthy external fuel tanks, serial numbers 0001 through 0006 were designed and fabricated at the contractor's facility under Government Contract Number F09603-79-C-P20002 to the requirements of contract engineering exhibit WR-ALC/MMS 79-21-3 dated April, 1979 to amendment two (2) dated September, 1979.

The filament winding and final assembly portion, inspection, functional testing and qualification testing were performed to the requirements of Technical Exhibit ASD/ENFEA-78 dated October, 1978 to amendment two (2) dated December, 1979. The qualification testing was performed at the contractor's facility and at various other facilities as listed in the introduction section of this report. The tooling manufactured to fabricate the six pre-production tanks shall be used to produce the flight test and production units.

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1.0 INTRODUCTION

This report represents the testing performed for Warner Robins ALC/MMSRCB, Robins Air Force Base, Georgia under Contract No. F09603-79-C-1642-P20002. The total contract effort performed included design fabrication and qualification testing of six (6) 450 Gallon Crashworthy Fuel Tanks for the U. S. Air Force H-53 Helicopter. The elapsed time for the completion of the complete effort was two years, that is from September 1979 to September 1981 with this qualification test report covering the period of time from December 1980 to July 1981. In addition to testing done at F.S.D., various outside testing facilities were used to complete all the test requirements. The following is a list of tests performed and the test facility responsible for the test:

TEST SECTION	TEST TITLE	TEST FACILITY
A	Individual Inspection	Fiber Science Division, SLC, UT
B	Examination of Product	Fiber Science Division, SLC, UT
C	Tank Contour	Fiber Science Division, SLC, UT
D	Assembled Tank Weight	Fiber Science Division, SLC, UT
E	Functional Test (Configuration Audit) (Standard Test)	 U.S. Air Force, Hill AFB, UT Sargent Fletcher Co., El Monte, CA
F	Pressure Test	Sargent Fletcher Co., El Monte, CA
G	Tank Capacity	Sargent Fletcher Co., El Monte, CA
H	Center of Gravity	Sargent Fletcher Co., El Monte, CA
I	Maintainability Demo.	Fiber Science Division, SLC, UT
J	Slosh & Vibration	Sargent Fletcher Co., El Monte, CA
K	Environmental Test	Sargent Fletcher Co., El Monte, CA
L	Static Loads	Sargent Fletcher Co., El Monte, CA
M	Forced Ejection (Gov. canceled test)	 Dynamic Science, Inc., Phoenix, AZ
N	Vapor Ignition	Dynamic Science, Inc., Phoenix, AZ
O	Ballistic (Gunfire Test)	Southwest Research Institute, San Antonio, TX
P	Fuel Fire (Samples)	U.S. Testing Co., Inc., L. A., CA
	(Actual Tank)	Dynamic Science, Inc., Phoenix, AZ

1.0 INTRODUCTION (Continued)

TEST SECTION	TEST TITLE	TEST FACILITY
Q	Electrostatic	K & S Laboratories, Westwood, MA
R	Lightning (Prototype)	Shaw Aero Devices, East Hampton, L. I., NY
S	Crash Impact	Dynamic Science, Inc., Phoenix, AZ

All scheduled tests were monitored by a Fiber Science Test Engineer and a Government representative with the exception of the Electrostatic Test performed by K & S Laboratories.

1.1 REASON FOR TEST

These tests were conducted to establish the performance characteristics of the 450 Gallon Crashworthy Filament Wound External Fuel Tank for the H-53 Helicopter designed and fabricated in accordance with the requirements set forth in the Technical Exhibit ASD/ENFEA-78 by Fiber Science Division. These tests included the following and were to be verified in accordance with the applicable paragraphs set forth in the Technical Exhibit:

TANK TESTS	REFERENCE PARAGRAPH
A. Individual Tank Inspection	4.4.1
B. Examination of Product	4.6.1
C. Tank Contour	4.6.8
D. Assembled Tank Weight	4.6.9
E. Functional Test	4.6.11
F. Pressure Test	4.6.12.2
G. Tank Capacity	4.6.13
H. Center of Gravity	4.6.10
I. Maintainability Demo.	4.6.16
J. Slosh & Vibration	4.6.14
K. Environmental Tests	4.6.17
L. Static Loads	4.6.18
M. Forced Ejection	4.6.19
N. Vapor Ignition	4.6.20
O. Ballistic	4.6.21
P. Fuel Fire	4.6.22
Q. Electrostatic	4.6.23
R. Lightning	4.6.24

In addition to these tests, a Crash Impact Test in accordance with Paragraph 4.6.25 was conducted to establish the primary performance characteristics of crashworthiness.

1.2 DESCRIPTION OF TEST SAMPLES

The test samples were six (6) filament wound composite crashworthy 450 Gallon External Fuel Tanks 219 inches in length, 29.5 inches in diameter with elliptical nose and tail sections fabricated in accordance with Fiber Science Engineering Drawing 2191-001 and the various subassemblies and details referenced on the engineering drawing. The test samples also included an Integral Pylon 27-450-4400 fabricated by Sargent Fletcher Company, fastened securely to the top of the tank by four (4) 9/16-18UNJF bolts. This pylon contained four (4) toggle mounting hooks actuated by a forced ejection mechanism for mounting to the H-53 Helicopter. Each tank, serialized 0001 through 0006, was instrumented, fueled and tested in accordance with the Qualification Test Procedures QTP-2191 Sections A through S as depicted in the test matrix of Paragraph 1.4.3.

1.3 DISPOSITION OF TEST SAMPLES

The spent test samples are currently located in the fenced Government Bond Area of the Fiber Science plant at 506 North Billy Mitchell Road, Salt Lake City, Utah, awaiting disposition or further evaluation by Warner Robins Air Force Base.

1.4 NARRATIVE ABSTRACT, CONCLUSIONS AND RECOMMENDATIONS

1.4.1 DEVELOPMENT PHASE

The development phase of the program contained various problems not all of which were known to Fiber Science prior to the release of the contract.

1.4.1.1 INITIAL PROBLEMS

Fiber Science was handicapped by lack of definition in the initial design phase of the 450 Gallon Filament Wound Composite Crashworthy Tank. In particular, this included drawings on the interface connection, fuel, air electrical fitting, and pylon attachment locations to the aircraft. Therefore, due to the lack of definition, the Government supplied Fiber Science with an existing metal tank and pylon, Part Numbers 27-450-48022 and 27-450-4400 respectively.

1.4.1.2 ADDITIONAL GOVERNMENT FURNISHED EQUIPMENT

An additional five (5) tank pylons were supplied by the Government to be used as an integral part of the qualification testing of the tanks.

1.4.1.3 SUBSCALE TESTING AND EVALUATION

As part of the design evaluation and to establish firm design criteria, subscale testing and fabrication approaches were performed on liner samples, simulated wall section samples and subscale models of the tank. This testing included permeability and adhesive testing using specified test fluids and known fuel resistant adhesives. Burn testing of various simulated tank wall sections, lightning testing of a subscale model of the tank and frame fabrication approaches were also evaluated in accordance with the requirements of the Technical Exhibit ASD/ENFEA-78.

1.4.1.4 LINER SELECTION

Two primary candidates were used for permeability testing, DUPONT's "HYTREL", a polyester elastomer and RIALSAN's "NYLON 11", a high strength low moisture absorbing nylon. Both materials passed the permeability test but because of the greater difficulty of bonding to NYLON 11, HYTREL polyester elastomer was selected for the liner.

1.4.1.6 TANK WALL SECTION EVALUATION

Wall section samples were fabricated and burn tests were performed at U.S. Testing Co., Inc., Los Angeles, California. From these tests it was determined that the insulative Polyisocyanurate Foam (I.C.U.) would not be required. This additional insulation only provided a minor improvement (10^{0} F to 20^{0} F at 175^{0} F to 2000^{0} F) in the insulative quality of the tank structural shell. Eliminating the foam also removed the concern about the friability of the I.C.U. foam which degrades the bonding of the epoxy impregnated filament winding to the honeycomb sandwich core of the tank.

1.4.1.7 LIGHTNING STRIKE EVALUATION

A subscale lightning test model of the tank was fabricated and shipped to Shaw Aero Devices of East Hampton, Long Island, New York. There it was lightning tested to determine if the selected Fiber Science design approach would withstand a high current lightning test. It was concluded that a conductive outer skin with nonconductive components on the inside of the tank was the most ideal approach after considering all other design parameters.

1.4.1.8 INTERNAL STRUCTURAL FRAME EVALUATION

Fiber Science's initial design approach was to build a tank with reinforced plastic frames and internal components. Because of the fabrication complexity of the frames and internal tubing and the risk of significant schedule slippage, Fiber Science elected to fabricate the frames and tubing of heat treated aluminum. This decision reduced lightning resistance of the tank to the extent that arcing occurred in the tank during the lightning test. This arcing originated primarily from the pylon attachment bolts to the internal aluminum frames.

1.4.1.9 ACCESS OPENING EVALUATION

It was determined at the critical design review that access openings on the side of the tank provided several locations where the tank might be susceptible to gunfire. Therefore, it was concluded to move the access openings to the top of the tank and reduce their number. This change provided for a lower profile of the access door cover and improved the gunfire resistance significantly. It, however, required a major redesign of the tank which impaired the program schedule and cost significantly.

1.4.2 FABRICATION PHASE

Six (6) tanks were all fabricated in accordance with the engineering drawings. It was found, however, that two significant revisions had to be made after fabrication of tank Serial Number 0001.

1.4.2.1 LINER MODULUS

There was insufficient elastic modulus in the liner of Serial Number 0001 to achieve good dimensional and buckling stability. During the winding operation buckling occurred in the liner about 12 inches from the end of the tank. A contingency plan was then executed. The liner was overlayed with a layer of epoxy impregnated glass cloth and cured in a mold. The buckled condition of tank Serial Number 0001 restricted its usage during qualification testing.

1.4.2.2 ACCESS OPENING

An additional access opening was also added to the tank forward of the fuel and air fittings to reduce the difficulty of assembly and disassembly.

1.4.3 QUALIFICATION TEST PHASE

The actual test matrix for qualification testing according to serial number was as follows:

SPECIFIED QUALIFIED TESTS	TEST PROCEDURE	REQUIRED TESTS					
		A	B	C	D	E	F
Individual Inspection	A	X	X	X	X	X	X
Examination of Product	B	X	X	X	X	X	X
Tank Contour	C	X	X	X	X		
Assembled Tank Weight	D	X	X	X	X	X	X
Functional Test	E					X	X
Pressure Test	F					X	X
Tank Capacity	G					X	X
Center of Gravity	H					X	
Maintainability Demo.	I					X	X
Slosh & Vibration	J					X	X
Environmental Test	K					X	
Static Loads	L					X	
Forced Ejection	M						
Vapor Ignition	N	X					
Ballistic (Gun Fire)	O						X
Fuel Fire	P					X	
Electrostatic	Q				X		
Lightning	R						X
Crash Impact	S		X	X	X		

1.4.3.1 INDIVIDUAL INSPECTION & EXAMINATION OF PRODUCT

All six 450 Gallon Filament Wound Survivable Tanks received an individual inspection and examination of product tests in accordance with the Technical Exhibit ASD/ENFEA-78. No significant problems other than those previously mentioned were encountered during these tests. However, subsequent testing(primarily environmental and pressure testing) re- →
vealed poor bonding of the attachment fittings and frames

to the tank walls. Corrective action has been taken to improve bonding techniques. Proper surface preparations and adhesive mixing will be verified by an inspector.

1.4.3.2 TANK CONTOUR

The tank contour was examined on Serial Numbers 0001 through 0004. Tank Serial Number 0001 was out of contour due to the buckled condition of the tail, but only in that area. The tank surface roughness, with the exception of Serial Number 0001, was approximately 1250 micro inches.

1.4.3.3 ASSEMBLED TANK WEIGHT

All six (6) assembled tanks including integral pylons failed to meet the specification weight requirements of 320 pounds. The weight variation from tank to tank was 7.4 lbs. The mean overweight condition was 24.0 lbs. Tank Serial Number 0001 is not included in these values because of the excessive weight increase (approximately 60 lbs.) by the application of a filler material used to improve the surface finish on the tank. The principal contributors to the overweight condition are liner thickness, frame design and graphite helical layer instead of graphite cloth.

1.4.3.3.1 ROTOCAST LINER WEIGHT

The rotocasting process used to produce the liner could not consistently produce a nominal .040 inch thick liner without some porosity. Therefore, to reduce porosity, the liner thickness was increased. The resulting liner weight increase was approximately 8 lbs. for each .010 inches of liner thickness increase. This was a major contribution to the tank overweight condition.

1.4.3.3.2 STRUCTURAL FRAME WEIGHT

The frame design was not fully optimized for strength-to-weight. Weight savings could probably be found in this area.

1.4.3.3.3 GRAPHITE HELICAL WEIGHT

The insulative graphite helical layer chosen over insulative graphite cloth was due to tank structural requirements and the securing of the graphite layer to the tank. Potential weight savings could be found in this area.

1.4.3.3.4 WEIGHT REDUCTION PROGRAM

Fiber Science does not recommend the initiation of a weight savings program. The trade-offs between tank weight, performance and cost have resulted in an over specification weight tank. Significant weight reduction cannot be made without major cost and schedule impact.

1.4.3.4 FUNCTIONAL TESTS

1.4.3.4.1 CONFIGURATION AUDIT FUNCTIONAL TEST

The configuration audit functional test was conducted on a H-53 helicopter at Hill Air Force Base. Tank Serial Number 0001, was successfully attached, fueled and defueled. The fuel probe and float switches did not operate properly. It could not be determined whether the cause was with the aircraft or the tank. It was determined, however, that the low level float switch was not required and it was not installed on the remaining five tanks.

1.4.3.4.2 STANDARD FUNCTIONAL TEST

Two (2) tanks, Serial Numbers 0005 and 0006, received the standard functional test. Initial testing disclosed that the vent holes had been deleted from the structural frames and one "U" bolt had not been installed. This allowed the fuel tube to short out the electrical connection of the fuel probe. After correcting these deficiencies, the functional test was successfully completed according to the specification requirements.

1.4.3.5 PRESSURE TEST

All tanks received a pressure test as part of the acceptance test procedure. However, only two tanks received pressure tests at the qualification test facility. Leakage was noted at most of the access openings due to poor bonding of these fittings to the tank liner wall. During the pressure test, the test medium (water) was forced into the sandwich core of the tank wall. This condition required lengthy drying before the environmental test could be conducted and also raised questions as to the actual cause of leakage during the environmental test.

1.4.3.6 TANK CAPACITY

The tank capacity test was also affected by the deleted vent holes in the structural frame. After providing a vent hole, the test was successful except for the following:

1.4.3.6.1 FILLER CAP LOCATION

It appeared that the filler cap location may be slightly too far aft on the tank because the tank was 5.96 gallons short of the required 450 usable gallons. This problem may, however, be due to the tolerance in the inclinometer used to position the tank in a two (2) degree nose down attitude. Fiber Science will investigate the problem. If the filler cap is improperly located, Fiber Science will see if it can be moved forward and up the tank without creating a refueling problem relative to helicopter clearances.

1.4.3.6.2 DRAIN TUBE LOCATION

The drain tube was also too close to the bottom of the tank, providing for insufficient sump capacity. The drain tube will be raised to correct the insufficient fuel sump problem.

1.4.3.7 CENTER OF GRAVITY

The center of gravity (C.G.) excursion of the tank was observed from a full condition to empty and was recorded at the specification requirements of 2^{o} nose down. The C.G. excursion was between tank station 94.0 and 108.9. The full C.G. was at station 108.9 and the empty C.G. at station 106.3.

1.4.3.8 MAINTAINABILITY DEMONSTRATION

A maintainability tank demonstration was performed using Serial Number 0005 and 0006 with no problems. The tank met the requirements within the time allotted by the specification.

1.4.3.9 SLOSH AND VIBRATION

Slosh and vibration demonstration showed no visible structural damage with the single exception of a crack in the lower web of the forward aluminum baffle plate where an access hole is located. The baffle shall be strengthened for the flight test and production units. The side of the probe in the 0006 tank was worn through due to improper installation. A caution note shall be added to the assembly procedure for this condition.

1.4.3.10 ENVIRONMENTAL TEST

The environmental test demonstrated the great insulative qualities of the tank wall by requiring 29 hours longer than the test chamber to achieve -65° F and 20 hours longer than the test chamber to achieve 130° F. The fear of a fire in the test chamber from fuel fumes from a tank that had previously leaked, being ignited by a spark from electrical fan motors inside the chamber, caused Fiber Science and the Government to conclude with the test facility that the high temperature environmental test be reduced to 130° F instead of the 160° F required by the specification.

During the test, leakage was noted in the nose section of the tank primarily in the area of the drain. Pieces of adhesive were also removed from the inside of the tank denoting a poor adhesive bond in the tank. This was the most serious problem found in all the qualification testing and as stated before, it will be properly addressed in the bonding proceedings for the flight and production tank fabrication.

1.4.3.11 STATIC LOADS TEST

The static loads test was successfully completed on tank Serial Number 0005. All loading conditions were met with the single exception that the testing facility requested not to test the tank to destruction because of the limitations of their test equipment. The highest load to which the tank was subjected was 165% of the limit load condition. It should be noted that the structural test facility and testing equipment used for the structural test of the 450 Gallon External Fuel Tank is the same facility used to test the U.S. Air Force F-15 600 Gallon and F-16 300 Gallon External Fuel Tanks as well as many others.

1.4.3.11.1 STRUCTURAL DAMAGE

The tank structural shell as well as the internal structural frame appeared to have experienced no structural damage nor was any detected from the strain gauge readings.

1.4.3.11.2 MOUNTING BOLT DAMAGE

Before the 165% limit load was released, a .10 inch gap was noted between one corner of the pylon and the tank. One of the Government supplied mounting bolts used to fasten the pylon to the structural frame of the tank was deformed and elongated according to the investigation conducted by the structural test facility engineer. Further investigation was conducted at Fiber Science with the removal of the structural frame adaptor to see if the threaded insert into which the bolt fastened was deformed. No evidence of deformation could be detected and the final conclusion was that the bolt had been improperly installed. A caution statement shall be added to the Job Card to prevent any recurrence of the problem.

1.4.3.12 FORCED EJECTION

The forced ejection test was not conducted in order to have a test unit for a third crash impact test. This decision was made by the Government and concurred with by Fiber Science. The test should be conducted for close up evaluation of the tank. The primary purpose for conducting such a test in the future would be for establishing engineering design criteria for current and future needs. The tank is capable of withstanding this test condition.

1.4.3.13 VAPOR IGNITION

The vapor ignition test was performed on tank Serial Number 0001. There was no visible damage to the tank structure. Both fuel and air fittings were blown from the tank. This was the result primarily of an oversight on the part of all parties concerned since to be truly representative of an actual aircraft installation, restrictive sockets representing the aircraft valve into which these fittings are installed should have been used for this test. The blowoff of the fitting would not have occurred had restrictive valve adaptors been used.

1.4.3.14 BALLISTIC (GUN FIRE) TEST

The ballistic test performed on the tank Serial Number 0006 was successful. There were problems relative to data extraction.

1.4.3.14.1 ENTRANCE RUPTURE

A .50 inch diameter hole approved by Fiber Science was drilled approximately 4½ inches to the left of the entrance rupture of the projectile for installation of a pressure transducer. This hole created a definite stress concentration in the tank wall and was not reinforced other than the resin used to install the transducer. Therefore, when the projectile entered the tank, the hydraulic ram pressures ruptured the fibers between the projectile entrance and the hole drilled for installation of the pressure transducer and also blew out the pressure transducer.

1.4.3.14.2 EXIT RUPTURE

The exit rupture was very small and about 135^{0} around the upper portion of the tank instead of on the tank centerline which was the ballistic path at impact. Approximately 30% of the ballistic fragments were trapped inside the tank.

1.4.3.14.3 BALLISTIC DATA

Pressure and strain data were unreliable and the exact peak pressure or stress levels in the tank wall are very questionable. The test was also conducted on a cloudy day and the high speed camera film was not suited for the occasion. Thus the quality is very poor and dark.

1.4.3.14.4 FUTURE BALLISTIC TESTING

Future tests should be run with underwater pressure transducers and with no penetrations through the tank wall other than that created by the projectile. Data reduction equipment should be in good working condition and operating properly. Fiber Science will also establish a more accurate strain level for ballistic testing in the future. Most of the strain gauges broke even though the tank did not.

1.4.3.15 FUEL FIRE

The fuel fire test was conducted on tank Serial Number 0005 with a slight breeze (approximately 10 knots). The fuel pan was insufficient in width for such a test with a slight wind and thus only about 75% of the circumference of the tank was engulfed in flames.

1.4.3.15.1 EXTINGUISHING THE FIRE

After 10 minutes of burn, the extinguishing of the fire began in accordance with the requirements of the specification. The tank was in test 30 minutes or 20 minutes beyond the specification requirements before the fire could be extinguished.

1.4.3.15.2 ON SITE INSPECTION

Excessive damage was done to the outside graphite windings due to the water force from the fire hose on the side of the tank, but these windings did protect the glass fibers sufficient to prevent their melting. The tank aluminum pylon facing melted away on the flame side. Each of the glass reinforced epoxy compression molded parts, that is, the nose cap, the access doors and the adaptor fittings held up well during the 1700° F fire.

1.4.3.15.3 POST FIRE EXAMINATION

The post fire examination of the tank showed it to be in better structural condition than tanks burned in previous fires. The liner had melted in the center and rear portions of the tank above the fuel level, but was just starting to melt in the nose portion indicating that the liner lasted most of the 30 minutes of burn. It should be noted that the loss of the liner does not indicate impending massive fuel loss. The inner winding, though not leak tight, does provide a high degree of fuel containment.

1.4.3.16 ELECTROSTATIC

The electrostatic test was performed on sample sections of the tank wall in accordance with the Technical Exhibit. According to the test facility, the tests were inconclusive as to whether or not a static electricity problem existed. Neither Fiber Science nor a Government representative were present for the test.

1.4.3.17 LIGHTNING

The lightning test performed first on a subscale model and later on a full scale tank was very successful relative to previously tested filament wound tanks which had ruptured through the tank wall when tested in a high current attachment environment.

1.4.3.17.1 SUBSCALE TEST

When testing the subscale model, no arcing was noted inside the tank except at the grounding lug on the bottom of the tank. This indicated that if all metal objects inside the tank were minimized, the lightning problem of past composite tanks would be solved.

1.4.3.17.2 FULL SCALE TEST

To lessen the schedule impact, some metallic parts such as the frame and the fuel tubes were designed into the full scale tank. Thus during the lightning test, arcing was noted inside the tank which indicates a possible internal explosion due to lightning strike. The danger in this is not that the tank will explode, but the collapsing of the fuel tubes, air tubes, fuel probe and float switch would make them inoperable. Future tank designs should eliminate as many metallic parts as possible.

1.4.3.18 CRASH IMPACT

Crash impact testing was performed on three tanks, Serial Numbers 0002, 0003 and 0004 with only partial success. Although the tanks did not break up, the rupture cracks were large enough to allow leakage well in excess of the specification requirements. Two tanks were dropped full of water from the specified height. The remaining tank was dropped 16 feet full of water.

1.4.3.18.1 CRASH IMPACT ANALYSIS

From subsequent structural analysis and testing done by Fiber Science on scale models, it was determined that the frames of the tank were too flexible in the lower portion causing the overall tank structure to be too flexible and break up under high bending loads.

1.4.3.18.2 CRASH IMPACT RECOMMENDATIONS

It is Fiber Science's recommendation that this test be rerun after a redesign of the frames and other aspects of the tank to increase its stiffness. Fiber Science would also recommend that the tank be dropped only 16 feet instead of the specified 25 feet. The 25 foot height seems excessive since it is greater than the H-53 Helicopter can withstand and is also higher than the drop test required for the U.S. Navy 650 CH-53E 650 Gallon Tank. The CH-53E tank is drop tested at 16 feet.

1.5 REFERENCES

The following documents not included in this report but which formed a part of the overall test requirements are as follows:

WARNER ROBINS AFB F09603-79-C-1642-P2002	Government Contract
WR-ALC/MMS 79-21-3	Contract Engineering Exhibit
FIBER SCIENCE DIVISION 2191-001	Tank - Installation 450 Gallon H-53
SARGENT FLETCHER 27-450-4400	Pylon Assembly 450 Gallon Fuel Tank

All other referenced documents, that is, Federal and Military Specifications can be acquired at the U.S. Government Printing Office, Washington, D. C.

1.6 TEST PLAN MODIFICATIONS

Changes to the test procedures QTP-2191 Sections "A" through "S" and changes to the Technical Exhibit ASD/ENFEA-78 were identified by Fiber Science Division relative to the 450 Gallon Filament Wound External Fuel Tank. These changes are summarized in Appendix C.

2.0 FACTUAL DATA

2.1 DESCRIPTION OF TEST APPARATUS

The description of the test apparatus for each test is described within the body of the individual test reports or in the applicable specifications referenced in the Qualification Test Procedures with the following exceptions:

A. Individual Inspection
B. Examination of Product
C. Tank Contour
D. Assembled Tank Weight

2.1.1 INDIVIDUAL INSPECTION

The individual inspection test included the manufacturing equipment used to fabricate the tank. The tank was filament wound on a cam operated servo control filament winding machine manufactured by Fiber Science Division, and powered by a 40 horse power hydraulic power supply. The tank was then cured according to the design specifications in a gas-fired recirculating oven to a maximum temperature of 275^{0} F $\pm$ 10^{0} F.

2.1.2 EXAMINATION OF PRODUCT

The test, with the exception of the use of a master gauge fabricated by Fiber Science Division to insure interchangeability between the tank 2191-001 and the integral pylon 27-450-4400, was conducted using standard calibrated inspection equipment. The actual equipment used is listed in the individual test reports or QTR-2191 Section "B".

2.1.3 TANK CONTOUR

The primary test apparatus used for the tank contour was an inspected and approved Fiber Science fabricated contour template. All other equipment was standard inspection equipment.

2.1.4 ASSEMBLED TANK WEIGHT

The assembled tank weight was verified by weighing the tank on a 500 pound capacity digital scale accurate to one hundredth of a pound.

2.1.5 TEST FACILITY APPARATUS

The remainder of the apparatuses used in the functional testing through crash impact are described in the individual test reports.

2.2 TEST DATA

Copies of all Qualification Test Procedures are summarized in Appendix A. Test reports, including all detailed data for these tests are summarized in the attached Appendix B.

APPENDIX C

CORRECTIONS TO

QUALIFICATION TEST PROCEDURES

AND

TECHNICAL EXHIBIT ASD/ENFEA-78

APPENDIX C

CORRECTIONS TO QUALIFICATION TEST PROCEDURES

AND TECHNICAL EXHIBIT ASD/ENFEA-78

A. QTP-2191 SECTION "A"

1. Page 3, paragraph 3.2.2 has been changed to read "2.5 psi" as specified by the technical exhibit paragraph 3.5.2.

2. Page 3, paragraph 3.2.3's reference to paragraph 3.2.2 is a reference to the preceding paragraph in the procedure (QTP-2191 Section "A") and not to the technical exhibit.

3. Page 5, paragraph 3.2.5.3 has been changed to read "300 psi" as specified by the technical exhibit paragraph 3.3.2.4.1.

4. Page 7, figure 1. The dimensions measured at points A & C are critical frame dimensions, dimension B is chosen halfway between A & C for a median dimension and dimension D is chosen for its location at the aft tangent line of the cylindrical section. Fiber Science could drop dimensions B and D but we feel they are critical to the dimensional integrity of the tank since they are not structurally supported and are inflatable. Therefore, Fiber Science recommends that paragraph 4.6.5 of the technical exhibit be changed to read ". . .four locations approximately 30 inches apart" or ". . .four locations not greater than 30 inches apart". Fiber Science prefers the latter statement.

5. Page 10, paragraph 4.2.2 has been changed to read "2.5 psi" as specified by the technical exhibit paragraph 3.5.2.

6. Page 11, paragraph 4.2.4.6 has been changed to read "2 inches minimum" as specified by the technical exhibit paragraph 4.2.4.6.

7. Page 12, paragraph 4.2.5.1. The method specified in paragraph 4.6.7.4.1 of the technical exhibit does not represent an accurate determination of resin content of the filament winding process which is the primary reason for this quality assurance provision. The access door portion of the tank contains a solid laminate approximately 1/4 of an inch of fiberglass and epoxy resin composite. Also this section has approximately 1/8 of an inch of reinforcing doilies of fiberglass and epoxy resin. The filament winding fibers are only 1/16 of an inch in thickness and therefore would only represent approximately 11% of the total resin content. The primary resin content being measured therefore would be that of the access door frame and reinforcements not the filament winding. No other location can be selected on the tank without destroying the tank or repeating the access door problem. Therefore, Fiber Science recommends that the verbage of paragraph 4.6.7.4.1 be removed and replaced with that of paragraph 4.2.5.1 of the qualification test procedure (QTP-2191 Section "A").

8. Page 13, paragraph 4.2.5.3 has been changed to read "300 psi" as specified by the technical exhibit paragraph 3.3.2.4.1.

9. Page 17, Ref. paragraph 4.2.2 has been changed to read "2.5 ± .25 psi" as specified by the technical exhibit.

10. Page 21, Ref. paragraph 4.2.5.1 technical exhibit should be revised in accordance with paragraph 7 of Appendix A.

11. Page 22, paragraph 4.2.5.3 has been changed to read "300 psi" as specified by the technical exhibit paragraph 3.3.2.4.1.

12. Other minor changes have been made to the procedure and are listed on the enclosed Engineering Change Notice (ECN) A791.

B. QTP-2191 SECTION "E"

1. Page 5, paragraph 3.3.2.1.1 was chosen prior to design values being established and has been revised to read ± 1.0 pico farads in accordance with the design values and MIL-G-26988 Rev. C.

2. Page 5, paragraph 3.3.2.1.2 was chosen prior to design values being established and has been revised to read ± 1.0 pico farads in accordance with the design values and MIL-G-26988 Rev. C.

3. Page 23, Ref. paragraph 4.5.2 "actual dry capacitance" has been changed to "actual wet capacitance".

C. QTP-2191 SECTION "J"

1. Page 5, paragraph 3.3.10. This test is a post slosh and vibration test and is performed in accordance with the technical exhibit paragraph 4.6.14. Therefore, it should not be changed.

2. Page 11, paragraph 4.7 (same as item 3.a).

D. QTP-2191 SECTION "K"

1. Page 3, paragraph 3.3. The plus or minus sign (±) has been removed from in front of 160^{o} F ± 10^{o} F.

E. QTP-2191 SECTION "M"

1. Page 3, paragraph 3.3 has been changed to 48 ± 2 inches test height for water to agree with paragraph 3.4.1.7.1 and 4.6.19 of the technical exhibit.

2. Pages, Figure 1 has been changed to 48 ± 2 inches test for water to agree with paragraph 3.4.1.7.1 and 4.6.19 of the technical exhibit.

F. QTP-2191 SECTION "N"

1. Page 3, paragraph 3.1 has been changed to include the addition of paragraph 4.6.20 of the technical exhibit.

G. QTP-2191 SECTION "S"

1. Page 3, paragraph 3.3; page 5, Figure 1; and page 6, Figure 2 have all been uniformly fixed to reflect a forward impact velocity of 39.6 ± 2 feet per second.